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ABSTRACT

This paper compares the old and new curricula of elementary mathematics and natural science in the Republic of China. This study, as the second phase of an evaluation period, tested a sample of the students while they were in the ninth grade and compared them to students who received the old curricula during their elementary studies. The data were gathered from 1,016 matched pairs of students for the national science and biology tests and from 968 matched pairs for the mathematics tests. Four instruments were developed for purposes of assessment: (1) elementary level mathematics achievement test; (2) secondary level mathematics ability test; (3) elementary level science achievement test; and (4) secondary level biology achievement test. There were significant differences on the elementary level mathematics test and the elementary level science test between the two groups of students, and no significant differences on the two secondary level tests. Differences by items and the results are discussed. (YP)

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ACADEMIC ACHIEVEMENT OF REPUBLIC OF CHINA STUDENTS USING OLD AND NEW MATHEMATICS AND SCIENCE CURRICULA

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INTRODUCTION

Background for the Study

In 1972 the Ministry of Education gave the Taiwan Provincial Institute for Schoolteachers' Inservice Education primary responsibility in research and development of all elementary school curricula. The first projects were the development of new mathematics and natural science curricula. These projects were carried out in two phases. Research and development work were conducted in phase I while phase II focused on dissemination, implementation and evaluation. Both projects are now in phase II. The study reported in this paper is a small part of the overall evaluation of the two curricula.

The new curricula underwent three separate pilot studies and revisions before nationwide use. The first pilot study was conducted at local schools by members of the research group. The more extensive second pilot was conducted in 96 experimental schools all over the province, 48 schools for mathematics and 48 schools for natural science. The third pilot study involved still another 65 schools. In this study, all classes in the selected schools used the experimental curricula in both mathematics and natural science.

The third pilot study began in September 1976 and lasted until June 1983 when the participating students graduated from elementary school. In April and May 1985 we tested a sample of the students while they were in the ninth grade and compared them to students who received the old curricula.

Rationale for the Study

We conducted the comparison on the students from the third pilot because the final curricula were nationally adopted in all schools, making it impossible to make any comparisons. In any case, the spirit of the new curricula was completely represented by the third experimental curricula and further changes were only fine tuning of the curricula concepts.

We have compared the achievement of the two groups of students (hereafter called old and new students) after six years of immersion because we feel that the curricula should be justified by their long term effects rather than short term gains.

This was not altogether an impartial study. The die was biased towards the new curricula and our new beliefs in what natural science and mathematics education ought to be like. Thus, the tests we used to compare the two groups favor material that are emphasized in the new curricula or taught in novel ways in

the new curricula, although the content of the questions were covered in both the new and old curricula. We feel that this was a justifiable approach, for we did not really want to know if the new curricula were better than the old. We knew they were better. We merely wanted to know if the new curricula successfully emphasize the concepts and skills that we wished explained.

In a way this was also an evaluation of our teacher training methods. The successful implementation of a curriculum reform project depends heavily on changing teachers. Each year of the project, the teachers from the experimental schools received three weeks of intensive training on the new curricula at the Institute. When teachers were trained at the Institute they were distributed experimental teaching aids so that they might learn how to use the new media and then take them back to their schools for experimental use. They also received additional guidance and attended demonstration classes for the duration of the study.

Comparison of the Old and New Curricula

Mathematics

In terms of content:

> "Both the old and new mathematics curricula highlight the acquisition and use of mathematics in everyday experiences, as well as the promotion of mathematics-related knowledge, concepts, reasoning, skills and motivation for learning. However, the new mathematics curriculum puts further emphasis on mathematical thinking and the development of positive attitudes toward mathematics. In addition, the new curriculum emphasizes the teaching of graphic materials and expands the curriculum domain into number, equation and use of figures and graphs while the old deems only number, computation and measurement." (translated from Chinese) "Revision of curriculum goals and a comparison between new and old curriculum content in mathematics" by [illegible], in "Elementary School Mathematics Curriculum Study" edited by Chen & Tang, 1978, p.1-3)

The new mathematics curriculum also gives more extensive coverage to aspects that students formerly had great difficulty with, such as decimals and numerical computation.

In terms of teaching method, the new curriculum emphasizes the use of instructional aids and active participation. In particular, teachers are instructed to use the following three aspects:

(1) Provide children more opportunities to participate in designing and learning learning activities, to engage in creative activities, to experiment with different methods of seeking solutions and to acquire flexible and appropriate methods of problem solving.

(2) Do not immediately explain or demonstrate solutions. Let children think, experiment, discuss, hypothesize, search for proofs, discover and express themselves. Develop their independence.

(3) Begin from the concrete and lead into abstract thinking.

Based on these characteristics of the new mathematics curricula we expected to find the new students significantly better in questions requiring the use of graphic materials, those requiring the search for regularities, and those requiring the use of decimals and numeration.

Natural Science

The old natural science curriculum was organized around knowledge systems, such as heat, light , sound, etc. The new curriculum is organized around scientific concepts and the relationships between them. For example, it deals with heat, light and sound as different forms of energy. It stresses the development of scientific concepts and scientific process with attention to human intellectual development.

In terms of teaching method, the old curriculum used traditional lectures to promote knowledge acquisition. Photographs, slides and objects were used to demonstrate concepts and to explain them more clearly. Experiments were conducted to prove what the teacher and the textbook taught. Not so in the new curriculum. The new teaching allows students direct contact with nature and natural events so that they can learn for themselves. Students are encouraged to engage in scientific activities that will enable them to learn scientific methods such as observation and experimentation. Through these activities they can acquire concepts and make conclusions about nature under the teachers' guidance. Thus, we expect the new students to perform better on items that were taught using direct manipulation and experimentation.

METHOD

Sampling

Approximately 19,000 students studied mathematics and science using the experimental curriculum. We sampled 5% or 1016 of these students and paired each one with a classmate in the same junior high school who learnt the materials using the old curriculum.

Sampling was done in the following manner. Each of the 65 experimental schools was sent a questionnaire requesting information concerning the junior high school attended by each student

who graduated in June, 1983. Based on the response to this questionnaire, we sent a second questionnaire to 20 junior high schools with large concentrations of previous experimental school students. From the second questionnaire, we found out the proportion of experimental students in each school and whether the students were administered intelligence tests upon entering junior high school. Each junior high school with IQ test data was sent background data forms for every eighth grade student to complete. The data requested included the student's name, elementary school attended, sex, birthdate, parents occupation and education, location of home (whether in a residential, commercial, military, fishing or mining area) and IQ score. The IQ data was filled in by a school administrator or teacher. The pairs of matching subjects were chosen using the information from these data sheets.

Socioeconomic status was calculated as an 11 point scale using a combination of parents' educational level and occupation. Five points are allotted to education and 6 points for occupation. First, education level and occupation of the two parents are assessed separately. SES is the sum of the higher of the two parents' educational score and occupation score.

The final sample came from 17 junior high schools chosen such that all geographical regions of the People's Republic of China are represented, with special consideration for including schools in remote mountainous or coastal areas. The number of students sampled from each school was determined according to the population of the city or county in which the school was located. For example, the population of Yuanjiang County is 0.4% of the total population of the counties sampled in the study. 1.4% of our sample came from Yuanjiang.

Subjects

The data reported are for 1916 matched pairs of students for the natural science and biology tests and for 568 matched pairs of students for the mathematics tests. 16 case subjects were used for all the tests but some students did not take the mathematics tests.

The tests reveal no difference between the two groups in age, sex, IQ, socioeconomic status and locality of residence.

Materials

Four instruments were developed to measure student achievement and ability. They were (1) Elementary level mathematics achievement test, (2) Secondary level mathematics ability test, (3) Elementary level science achievement test, and (4) Secondary level biology achievement test.

Construction of the instruments involved all the members of the mathematics and natural science research teams which

included professors and experts from the universities as well as experienced elementary schoolteachers. The initial pool of elementary level items were compiled by elementary schoolteachers who had extensive experience in achievement test construction from many years of participation at the Institute. The initial pool of secondary level mathematics items were written by three junior high schoolteachers specially invited to participate in the test construction. Items for the biology achievement test were first written by Professor Yang of the National Taiwan Normal University.

For each instrument, approximately twice as many items as needed were first developed and piloted. The first set of pilot data was examined for error rate, error patterns and discriminability, then revised and piloted again on other groups of eighth graders. A third round of piloting was conducted for the science and biology tests before final item selection. The final items used were chosen to give a reasonable level of difficulty using items of the highest discriminability. The numbers of students participating in each pilot varied for the different instruments. They ranged from 100 to 548. In each case, both old and new students were tested.

There were ten items on the elementary level mathematics test, beginning with the easiest items in basic computation and progressing to more difficult items such as calculation of volume, percentages and proportions. All of them were word problems worth 10 points.

The secondary level mathematics ability test had only five items. Aside from the first item, which required the student to solve a quadratic equation, all the items involved concepts to be covered in junior high school but which could be solved using knowledge and skills learnt in elementary school. Each problem was worth 20 points with partial scores given for partial answers.

There were 27 items on the elementary level natural science test, including 9 items in geology and 6 items each in physics, chemistry and biology. The majority were multiple choice items but a few required students to write down a response. Some items were related to others, forming clusters around a theme. Another characterictic of this test was that there were many illustrations and diagrams, some designed to test the students' observation skills and others to increase the students' comprehension of the problem. Each item on this test was worth one point.

The secondary level biology test had 22 items covering four areas. The four areas were knowledge and comprehension, reasoning and application, value and practical experimental skill. There were unequal numbers of items in each area and unequal number of points allotted to each question. The test is a mixture of multiple choice items, fill-ins, computations and written responses.

Procedure

In March [illegible] ... ensure that ... acceptable ... completed by the end of ...

Subjects were tested on two consecutive days in each school. In half of the schools the mathematics tests were administered on the first day, and in the other schools the [illegible] science tests were administered first. On each testing day, the elementary level test was administered first.

Student lists were mailed to the schools at least three days before testing to enable proper arrangements for space, time and effective coordination. Test administration was done by Institute staff with assistance from the school staff.

RESULTS AND DISCUSSION

Elementary Level Mathematics Achievement Test

Table 1 shows the results from the elementary level mathematics achievement test. The new students were better than the old on every question with the new students scoring significantly above the old students in total score ($t = 2.12$, $p < .01$). The new students also performed significantly better on five of the ten questions. The questions on which [illegible] on division using decimals, question 6, on calculation of percentages and the last three questions which were on calculation of [illegible], use of a graph and making a reduced drawing.

It is gratifying to note that the new students did so much better than the old students ($p < .001$) in the questions requiring use of graphic materials, a main emphasis in the new curriculum. The questions that did not produce significant differences we consider conceptually simpler -- addition of fractions and whole numbers, multiplication of whole numbers and decimals, and subtraction using a weighing scale. These results suggest that the new curriculum has been successful in teaching and emphasizing the more difficult mathematical concepts.

Secondary Level Mathematics Ability Test

Table 2 shows the results of the secondary level mathematics ability test. While the total score is not significantly different for the two groups ($t = 1.49$, [illegible], not significant) there are indications that the new curriculum has more lasting effects as we can see by examining the individual questions. The first question requests the solution of a quadratic equation. This is entirely taught in junior high school and is pure computation, so we did not really expect a significant difference

between the two groups. We are somewhat surprised and pleased to see that the new students significantly outperformed the old ($t(1,967)=3.35$, $p<.01$). Apparently the good effects of the new curriculum remain long enough to help students learn more effectively in secondary school. While the new curriculum does not emphasize computation as much as the old curriculum did we find that the new students do as well as the old students and sometimes better.

The results from question 2 shows that the many lessons spent on letting students search for their own solutions has paid off. In this question, students are required to find and make use of regularities in assigning people into groups.

The third question produced a significantly better performance for the new students ($t(1,967)=2.02$, $p<.05$). Again, it tells us the time and care taken to introduce place value in elementary school has helped students learn how to apply this knowledge in dealing with high school algebra problems.

No difference was detected in the performance of the two groups of students in the last two questions. The fourth question is a relatively simple problem of rule extension. We are disappointed that the last question did not discriminate old and new students for we feel that it is a question that calls for creative thinking, something that our teaching method had tried to foster.

Elementary Level Natural Science Achievement Test

Table 3 shows the results of the elementary level natural science test. Matched group t-tests indicated significant differences between the two groups on the total test score ($t(1,1015)=4.27$, $p<.001$) and on the geology and physics areas ($t(1,1015)=3.5$, $p<.001$ and $t(1,1015)=4.63$, $p<.0001$, respectively). Although we would have liked to see significant differences between old and new student achievement in all areas, these data reflect the extent of new curricular changes. The most extensive changes in the curriculum were in geology and physics where active exploration and creative thinking have been promoted with many new instructional aids. Comparatively fewer changes have been made in chemistry and biology.

Looking at the individual questions, the excellent performance of the new students in the geology part of the test were all in the question cluster dealing with the length and direction of shadows. While both old and new curricula dealt with similar content regarding shadows, the old students only observed the teacher casting shadows and explaining the results. The new students, in contrast, had personal experience casting shadows in the classroom. When the weather permitted, they also experimented with shadows outdoors. Obviously, this active experience has made a strong imppression on them.

Two other question clusters in the geology part of the test were on reading information from tables and dealing with spatial relations. We expected less of a difference in table reading which requires less creativity and active experience. The teaching of spatial relations , a main emphasis of the new curriculum, failed to show any significant difference between old and new students and should perhaps undergo further study and improvement.

We feel that the results point to the overall success of the new physics curriculum. In four of the six questions the new students have learnt significantly better than the old students. All questions dealt with concepts or methods in which students were allowed to explore and experiment on their own. The two questions that did not differentiate old and new students have the lowest pass rates on the entire test. Perhaps these concepts are inherently difficult so that even with vast amounts of exploration and expert teaching, we are unable to move the students beyond the level achieved by the old curriculum. We will also be exploring ways in which the teaching of the concepts covered in these two questions might be improved further.

As we mentioned earlier, the lack of significant difference between old and new students in the chemistry and biology areas could be due to the lack of difference in the curricula themselves. However, three questions did extract significantly different performance between the two groups, and in one of them the old students were significantly better than the new students. We do not have any handle on why these three questions out of the twelve questions in these two areas should differentiate the two groups.

Secondary Level Biology Test

Table 4 shows the results of the secondary level biology achievement test. There was no overall difference between the two groups' performance and significant differences in only two out of the 21 questions on the test. We believe that there are two main reasons for the lack of difference. First, the differences between the old and new curricula in biology are less extensive, as indicated by the results from the elementary level test and from a comparison of the curricular contents. Second, the test covered material learnt in junior high school in which both groups of students were taught using the same materials by the same teachers using the same methods.

We do not have any good explanations as to why the two particular questions produced superior performance in the new students. However, one of the questions concerned preservation and respect for the ecological environment. We would like to think that the new curriculum has instilled a lasting love and respect for their natural surroundings. If this is indeed so, then the new natural science curriculum has succeeded beyond our wildest dreams.

TABLE 1

MEAN SCORES FOR NEW AND OLD STUDENTS
ON THE
ELEMENTARY LEVEL MATHEMATICS ACHIEVEMENT TEST

Item #	New	Old	Matched t
1	8.96	8.79	1.67
2	6.20	5.62	3.06 **
3	7.02	6.74	1.55
4	7.45	7.41	0.26
5	7.52	7.46	0.35
6	6.20	5.84	2.15 *
7	7.37	7.27	0.70
8	6.93	6.21	4.25 ***
9	8.62	8.13	3.71 ***
10	7.78	7.32	3.61 ***
TOTAL	73.95	70.91	2.92 **

* p<.05
** p<.01
*** p<.001

TABLE 2

MEAN SCORES FOR NEW AND OLD STUDENTS
ON THE
SECONDARY LEVEL MATHEMATICS ABILITY TEST

Item #	New	Old	Matched t
1	9.20	8.04	3.35 **
2	8.29	7.42	2.69 **
3	16.88	16.32	2.02 *
4	14.04	13.63	1.43
5	9.62	9.96	-0.95
TOTAL	57.91	56.17	1.44

* $p<.05$
** $p<.01$

TABLE 3

PERCENTAGE CORRECT FOR NEW AND OLD STUDENTS
ON THE
ELEMENTARY LEVEL NATURAL SCIENCE ACHIEVEMENT TEST

Area	Item #	New	Old	Matched t
Geology	1	73.33	69.88	1.84
	2	69.98	70.97	-0.44
	3	77.56	72.64	2.67
	4	65.16	60.53	2.31 *
	5	72.83	63.88	4.45 ***
	6	77.93	73.10	1.59
	7	63.58	59.45	2.03 *
	8	80.71	80.31	0.23
	9	45.37	47.74	-1.11
	TOTAL	69.61	66.71	3.51 ***
Physics	10	65.43	60.14	2.63 **
	11	18.80	19.47	-0.40
	12	63.68	59.06	2.21 *
	13	47.74	39.76	3.90 ***
	14	60.04	55.41	2.21 *
	15	37.01	32.27	1.83
	TOTAL	48.79	44.56	4.64 ***
Chemistry	16	78.15	78.25	-0.06
	17	48.52	49.70	-0.57
	18	63.78	59.74	1.96 *
	19	85.53	84.25	0.83
	20	68.41	64.96	1.83
	21	81.30	78.94	1.39
	TOTAL	70.95	69.31	1.80
Biology	22	53.74	52.26	0.68
	23	49.41	54.43	-2.29 *
	24	88.09	88.19	-0.07
	25	55.71	50.39	2.52 *
	26	43.90	41.83	0.97
	27	87.80	85.24	1.69
	TOTAL	63.11	62.06	1.18
TOTAL FOR THE TEST		63.18	60.65	4.27 ***

* $p<.05$
** $p<.01$
*** $p<.001$

TABLE 4

PERCENTAGE CORRECT FOR NEW AND OLD STUDENTS
ON THE
SECONDARY LEVEL BIOLOGY ACHIEVEMENT TEST

Area	Item #	New	Old	Matched t
Knowledge	1	85.63	83.46	1.45
&	2	50.00	48.72	0.63
Comprehension	4	44.69	44.19	0.23
	6	49.70	52.07	-1.12
	11	8.76	7.38	1.16
	17	33.37	35.14	-0.88
	18	42.03	42.81	-0.39
	TOTAL	44.88	44.82	-0.13
Reasoning	3	74.30	74.02	0.71
&	5A	51.28	49.80	0.70
Application	7	66.04	61.32	2.32 *
	8	32.97	33.07	-0.05
	9	60.63	57.68	1.41
	10	7.09	6.99	0.09
	12	82.28	83.07	-0.52
	13	11.22	12.11	-0.67
	14	19.98	18.11	1.14
	15	44.39	45.57	-0.55
	TOTAL	45.02	44.17	0.22
Value	5B	29.13	30.51	-0.69
	20	65.94	59.84	2.90 **
	TOTAL	47.54	45.18	1.86
Practical	16	22.34	21.56	0.46
Study	21	6.40	5.81	0.57
	TOTAL	14.37	13.69	0.66
TOTAL FOR THE TEST		37.95	36.97	1.62

* $p<.05$
** $p<.01$